NAIC-ID(RS)T-0061-96

NATIONAL AIR INTELLIGENCE CENTER

MEASURING THE EFFICIENCY OF CHLORINE UTILIZATION
OF SINGLET OXYGEN GENERATOR

by

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HUMAN TRANSLATION

NAIC-ID(RS)T-0061-96 12 April 1996

MICROFICHE NR: 96C000324

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English pages: 7

Source: Yingyong Jiguang (Applied Laser), Vol. 15, Nr. 5, October 1995; pp. 222-224

Country of origin: China
Translated by: SCITRAN
F33657-84-D-0165
Requester: NAIC/TATD/Bruce Armstrong
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ABSTRACT Principles and apparatus associated with the measurement of singlet oxygen $O_2(^1\Delta)$ generator chlorine utilization are presented. At a fixed chlorine flow rate, utilization rates measured in association with rotating disk type $O_2(^1\Delta)$ generators can reach 92%.

KEY WORDS Efficiency of chlorine utilization Singlet oxygen generator Chemical oxygen-iodine laser

1 CHEMICAL OXYGEN IODINE LASERS

Chemical oxygen iodine laser systems are as shown in Fig.1. In them, within rotating disk $(O_2(^1\Delta))$. generators [1,2], a hydrogen peroxide alkaline solution is added. When this goes through chlorine gas--on rotating plate surfaces--the reactions described below are gone through, producing $O_2(^1\Delta)$

$$Cl_2 + H_2O_2 + MOH \longrightarrow O_2(^1\Delta) + 2MCl + 2H_2O \quad (1)$$

In this, M=Li,K,Na, and so on.

In optical cavities, $(O_2(^1\Delta)$ and iodine atoms collide, transfering energy to produce iodine atoms in excited states $O_2(^1\Delta)$. $O_2(^1\Delta)$ emits to produce laser light of 1.215 μm:

$$O_2(^1\Delta) + I(^2P_{3/2}) \longrightarrow I^*(^2P_{1/2}) + O_2(^3\textstyle\sum) \quad (2)$$

$$I^*(^2P_{1/2}) \longrightarrow I(^2P_{3/2}) + h\nu \quad (3)$$

Of course, $O_2(^1\Delta)$ is the power source for chemical oxygen iodine lasers. In $O_2(^1\Delta)$ generators, it is hoped that a fixed amount of chlorine will be able to produce as much $O_2(^1\Delta)$ as possible. That is the same as saying that efficiency of chlorine utilization must be as high as possible. As a result, chlorine utilization efficiency it the primary index to measure 1 generators. It is also an important index [3] to measure overall performance of chemical oxygen iodine lasers.

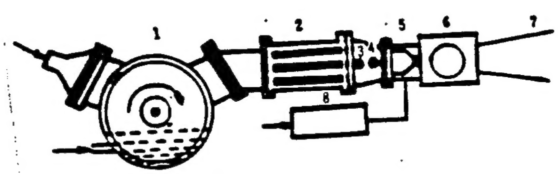

Fig.1 Chemical Oxygen Iodine Laser System Schematic

Key: 1. $O_2(^1\Delta)$ Generator 2. Cold Well 3. Chlorine Residue Measurement Aperture 4. Overall Pressure Measurement Aperture 5. Supersonic Spray Nozzle 6. Optical Cavity 7. Connection to Vaccuum Pump
8. Iodine Pool

2 MEASUREMENT PRINCIPLES AND APPARATUS

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On the basis of the Bier (phonetic) law, residual oxygen partial pressure is:

$$P_R = -[\ln(I/I_o)]/\varepsilon l \quad (4)$$

In this, Io is incident optical strength; I is transmited optical strength; l is absorption pool length; and, ε is absorption coefficient.

Fig.2 is a schematic diagram of a system for measuring chlorine absorption coefficients. Making use of deuterium lamps to act as light sources [4], the central wave length band through light filters is 325nm. Band width is 10nm. Pool length is 500mm. The relationship curve associated with ln(I/Io) and Pr is as shown in Fig.3. From the slope, it is possible to obtain chlorine absorption coefficients with regard to 325nm wave length light. The numerical value is 0.47Pa-1cm-1 .

During actual processes of operation associated with oxygen iodine chemical lasers, chlorine and helium gas are introduced into $O_2(^1\Delta)$ generators at the same time. Assuming that flow amounts of chlorine and helium at entry locations of generators are, respectively, $\dot{W}_{cl}$ and $\dot{W}_{He}$, the

$$P_T = P_{cl} + P_{He}, \quad (5)$$

$$n = P_{He}/P_{cl} = \dot{W}_{He}/\dot{W}_{cl} \quad (6)$$

corresponding partial pressures are, respectively, Pci and PHe . The partial pressure ratio is n. Total pressure is PT . Then, the residual chlorine rate is

$$R = P_R/P_{cl} = (n+1)P_R/P_T \quad (7)$$

The chlorine utilization efficiency is

$$U_c = 1 - (n+1)P_R/P_T \quad (8)$$

Therefore, as long as one measures $O_2(^1\Delta)$ generator output location residual chlorine partial pressures PR and total pressure PT , on the basis of equation (8), it is possible to obtain rotating disk type $O_2(^1\Delta)$ generator chlorine utilization efficiencies.

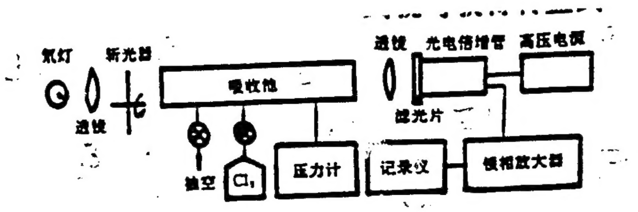

Fig.2 Schematic for Chlorine Absorption Coefficient Measurement System

Key: (1) Deuterium Lamp (2) Optical Chopper (3) Lens (4) Absorption Pool (5) Vaccuum (6) Lens (7) Optical Filter (8) Photoelectric Multiplier Tube (9) High Voltage Power Source (10) Pressure Guage (11) Recording Instrument (12) Phase Lock (unclear) Amplifier

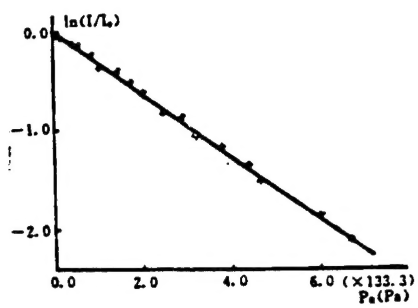

Fig.3 Relationship Between In(I/Io) and PR

3 EXPERIMENTAL RESULTS AND CONCLUSIONS

We measure chlorine utilization efficiencies after 1 generator output and before optical cavity supersonic spray nozzles (see Fig.1). The reason is that, during oxygen iodine chemical laser operation--besides needing to introduce such gases as chlorine, helium, iodine, and so on--small quantities of water vapor still exist. Therefore, it is, first of all, necessary to consider whether or not background radiation and absorption interference exist. Experimental measurements verify that various types of background interference can be ignored in calculations.

Fig.4 is a typical chlorine utilization efficiency curve during oxygen iodine chemical laser operational processes. Within an interval of 0-1 seconds, no gases at all have come in. The whole system is in a state of vaccuum. The survey light strength at this time Io is made to be 100 (arbitrary unit). Within the period of 1-3 seconds, helium comes in first, and, after that, iodine comes in. There are no changes at all in Io. This clearly shows that various types of background interference can be ignored in calculations. Beginning from second number 3, chlorine gas is added in. After the entry of chlorine, due to probe light absorption by unreacted chlorine, that is, residual chlorine, Io rapidly changes into I. Within approximately 3-8 seconds, I is an average of 74. At the same time, total pressure PT = 4532Pa. The ratio between helium and chlorine n = 3.93. On the basis of equations (4) and (7), it is possible to obtain residual chlorine partial pressures and residue rates that are, respectively, 72Pa and 8%. On the basis of equation (8), utilization efficiency for chlorine is 92%. Beginning with second number 8, chlorine utilization efficiencies begin to drop continuously. Up to second number 13, when the entry of gas is stopped, chlorine utilization efficiencies drop from 92% to 63%. This may possibly be because, after chlorine comes in, alkaline solution concentrations on the surface of 1 generator rotating disks as well as their peripheries drops continuously. Causing, within a very, very short few seconds, it to then be too late to do replacement. This has already been verified by later experiments.

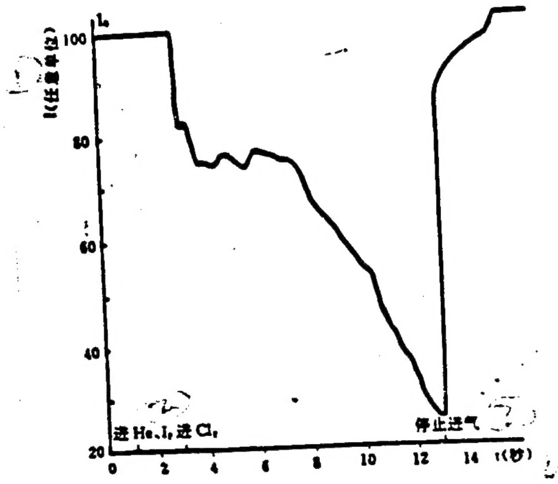

Fig.4 Relationship Between Chlorine Utilization Efficiency and Time

Key: (1) Arbitrary Unit (2) Enter He, I(unclear), Enter Cl (unclear) (3) Stop Gas Entry (4) Seconds

Due to our $O_2(^1\Delta)$ generators carrying on them alkaline solution storage tanks, the alkaline solution in alkali pools is, therefore, relatively abundant. Although each /224 iteration of testing causes concentrations of alkaline solution on the surfaces of rotating disks and their peripheries to drop, so long, however, as the interval between two iterations of tests is ten or fifteen minutes, and, at the same time, $O_2(^1\Delta)$ generator rotating disks do not stop turning, a complete replacement of alkaline solution is effected on rotating disk surfaces as well as their peripheries. In this way, chlorine utilization efficiencies associated with each iteration of tests can be basically maintained invariable. For example, with regard to continuously making 5 iterations of tests, chlorine utilization efficiencies are maintained within 92±1%. This also explains relatively good reproducibility of measurements. However, if the interval between two iterations of tests is only around 3 seconds, then there is not enough time to completely renew alkaline solution on rotating disk surfaces as well as their peripheries. Chlorine utilization efficiencies then gradually drop. For example, making 4 iterations of tests continuously in this way, chlorine utilization efficiencies are, respectively, 92%, 91%, 89%, and 87%. When $O_2(^1\Delta)$

generators do not carry alkaline solution storage tanks, alkaline solution in alkali pools is relatively scarce. Making 5 continuous iterations of tests--even though the interval between each iteration of tests is ten or fifteen minutes--chlorine utilization efficiencies also gradually drop 2 percentage points.

The number of turns of $O_2(^1\Delta)$ generator rotating disks has a relatively great influence on chlorine utilization efficiencies. When turn numbers increase from 20 turns/minute to 40 turns/minute, chlorine utilization efficiencies increase 18 percentage points.

When the total surface area of $O_2(^1\Delta)$ generator rotating disks increases 1 fold, chlorine utilization efficiencies increase 15 percentage points.

To summarize what was discussed above, increasing the concentration of alkaline solution in $O_2(^1\Delta)$ generators, enlarging the surface area of rotating disks, and increasing the number of turns of rotating disks all are capable of increasing $O_2(^1\Delta)$ generator chlorine utilization efficiencies within a certain range.

Also participating in these tests were comrades of teams 701 and 702.

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